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Declaration

I, Michihiko Matsuba, President of Fukuyama Sangyo Honyaku Center, Ltd., of 16-3, 2-chome, Nogami-cho, Fukuyama, Japan, do solemnly and sincerely declare that I understand well both the Japanese and English languages and that the attached document in English is a full and faithful translation, of the copy of Japanese Unexamined Patent No. Hei-7-227089 laid open on August 22, 1995.

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DRIVE CONTROL UNIT FOR ULTRASONIC MOTOR

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Applicant: Nikon Corporation

Inventor: Daisuke SAYA

Patent Attorney: Hisao KAMATA, et al.

SPECIFICATION

[TITLE OF THE INVENTION]

Drive control unit for ultrasonic motor

[Abstract] To shorten rise time when an ultrasonic motor starts up.

[Composition] A drive control unit 10 for an ultrasonic motor comprises a drive circuit 11 which supplies a drive signal to an ultrasonic motor 1, a detecting means 12 for detecting the number of revolutions of the ultrasonic motor 1, an oscillating condition and the like, a system control means 13 for controlling a driving system of the ultrasonic motor 1, a storage means 14 which holds information concerning drive frequencies of the ultrasonic motor 1 in storage, and a

selecting means 15 which selects, based on a motion instructing signal issued from the system control means 13, a drive controlling value from the storage means 14. The system control means 13 drives the ultrasonic motor 1, first, with a drive frequency where maximum starting torque is obtainable and, then, with a drive frequency where a target number of revolutions is obtainable.

[WHAT IS CLAIMED IS;]

[Claim 1] A drive control unit for an ultrasonic motor which controls drive of an ultrasonic motor comprising a stator having a piezoelectric body which is excited by a drive signal and an elastic body which generates progressive oscillatory waves due to excitation of said piezoelectric body and a mobile body which is in contact with said stator and is driven, wherein provided with;

a storage means for storing information concerning drive frequencies of said ultrasonic motor,

a detecting means for detecting a driving condition of said ultrasonic motor,

a control means which selects a drive frequency for which approximately maximum starting torque is obtainable based on the information stored in said storage means and selects, if the driving condition detected by said detecting means reaches

an appointed condition, a drive frequency for which a target number of revolutions is obtainable based on the information stored in said storage means, and

a driving force supplying means for supplying a drive signal based on the drive frequency selected by said control means to said piezoelectric body of said ultrasonic motor.

[Claim 2] A drive control unit for an ultrasonic motor which controls drive of an ultrasonic motor comprising a stator having a piezoelectric body which is excited by a drive signal and an elastic body which generates progressive oscillatory waves due to excitation of said piezoelectric body and a mobile body which is in contact with said stator and is driven, wherein provided with;

a storage means for storing information concerning drive frequencies for a plurality of drive voltages of said ultrasonic motor,

a detecting means for detecting a driving condition of said ultrasonic motor,

a control means which selects a drive voltage and a drive frequency for which approximately maximum starting torque is obtainable based on the information stored in said storage means and selects, if the driving condition detected by said detecting means reaches an appointed condition, a drive voltage

and a drive frequency for which a target number of revolutions is obtainable based on the information stored in said storage means, and

a driving force supplying means for supplying a drive signal based on the drive voltage and drive frequency selected by said control means to said piezoelectric body of said ultrasonic motor.

[Claim 3] A drive control unit for an ultrasonic motor which controls drive of an ultrasonic motor comprising a stator having a piezoelectric body which is excited by a drive signal and an elastic body which generates progressive oscillatory waves due to excitation of said piezoelectric body and a mobile body which is in contact with said stator and is driven, wherein provided with;

a storage means for storing information concerning drive frequencies for a first drive voltage of said ultrasonic motor and information concerning drive frequencies for a second drive voltage lower than the first drive voltage,

a detecting means for detecting a driving condition of said ultrasonic motor,

a control means which selects said second drive voltage and a drive frequency where approximately maximum starting torque is obtainable with said second drive voltage based on the

information stored in said storage means, and selects, if the driving condition detected by said detecting means reaches an appointed condition, said first drive voltage and a frequency where approximately maximum starting torque is obtainable with said first drive voltage, and selects, if the driving condition detected by said detecting means reaches an appointed condition, a drive frequency where a target number of revolutions is obtainable with said first drive voltage based on the information stored in said storage means, and

a driving force supplying means for supplying a drive signal based on the drive voltage and drive frequency selected by said control means to said piezoelectric body of said ultrasonic motor.

[Claim 4] A device control unit for an ultrasonic motor as set forth in Claims 1 through 3, wherein

said storage means stores the relationship between the drive frequency, starting torque, and number of revolutions of said ultrasonic motor.

[Claim 5] A device control unit for an ultrasonic motor as set forth in Claims 1 through 4, wherein

said detecting means detects the number of revolutions of said ultrasonic motor.

[Claim 6] A device control unit for an ultrasonic motor as

set forth in Claims 1 through 4, wherein

said detecting means detects a signal from a monitor electrode of said ultrasonic motor.

[Claim 7] A device control unit for an ultrasonic motor as set forth in Claims 1 through 4, wherein

said detecting means detects the phase difference between an input signal of said ultrasonic motor and a signal from a monitor electrode of said ultrasonic motor.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention] This invention relates to, in terms of an ultrasonic motor comprising a stator which generates progressive oscillatory waves by being excited and a movable body which is in contact with said stator and is driven, a drive control unit for controlling drive of this ultrasonic motor.

[0002]

[Prior Arts] Priorly, as a unit for controlling drive of this type of ultrasonic motor, for example, a unit which is disclosed in Japanese Unexamined Patent Publication No. Sho-59-156168 is known. In this unit, frequencies of a voltage to be applied are changed in sequence, drive speed of the mobile body at each frequency is measured, and a frequency at which the measured value becomes maximum is stored so that drive is carried out

at a voltage having this frequency stored. Thus, the drive frequency is controlled so as to be in a resonance condition with respect to the shape and size of an oscillator, drive speed of the ultrasonic motor becomes maximum, and driving efficiency is improved.

[0003]

[Themes to be Solved by the Invention] However, while rising response at start-up becomes important in a system where high-speed motion is required, in the aforementioned prior drive control unit for an ultrasonic motor, maximum response could not always be obtained. Accordingly, there has been a problem such that it takes time to reach an objective number of revolutions. Furthermore, if driving time becomes long, there has been a problem such that a current consumption product (a product of current consumption and time) becomes great.

[0004] The present invention is made in order to solve the above-mentioned problems and aims to shorten rise time when an ultrasonic motor starts up.

[0005]

[Means for Solving Themes] In order to achieve the aforementioned object, a first solution means of a drive control unit of an ultrasonic motor according to the present invention is a drive control unit (10) for an ultrasonic motor

which controls drive of an ultrasonic motor (1) comprising a stator (2) having a piezoelectric body (2a) which is excited by a drive signal and an elastic body (2b) which generates progressive oscillatory waves due to excitation of said piezoelectric body and a mobile body (3) which is in contact with said stator and is driven, wherein provided with;

a storage means (14) for storing information concerning drive frequencies of said ultrasonic motor,

a detecting means (12) for detecting a driving condition of said ultrasonic motor,

a control means (13) which selects a drive frequency for which approximately maximum starting torque is obtainable based on the information stored in said storage means and selects, if the driving condition detected by said detecting means reaches an appointed condition, a drive frequency for which a target number of revolutions is obtainable based on the information stored in said storage means, and

a driving force supplying means (11) for supplying a drive signal based on the drive frequency selected by said control means to said piezoelectric body of said ultrasonic motor.

[0006] A second solution means is a drive control unit for an ultrasonic motor which controls drive of an ultrasonic motor comprising a stator having a piezoelectric body which is

excited by a drive signal and an elastic body which generates progressive oscillatory waves due to excitation of said piezoelectric body and a mobile body which is in contact with said stator and is driven, wherein provided with;

a storage means for storing information concerning drive frequencies for a plurality of drive voltages of said ultrasonic motor,

a detecting means for detecting a driving condition of said ultrasonic motor,

a control means which selects a drive voltage and a drive frequency for which approximately maximum starting torque is obtainable based on the information stored in said storage means and selects, if the driving condition detected by said detecting means reaches an appointed condition, a drive voltage and a drive frequency for which a target number of revolutions is obtainable based on the information stored in said storage means, and

a driving force supplying means for supplying a drive signal based on the drive voltage and drive frequency selected by said control means to said piezoelectric body of said ultrasonic motor.

[0007] A third solution means is a drive control unit for an ultrasonic motor which controls drive of an ultrasonic motor

comprising a stator having a piezoelectric body which is excited by a drive signal and an elastic body which generates progressive oscillatory waves due to excitation of said piezoelectric body and a mobile body which is in contact with said stator and is driven, wherein provided with;

a storage means for storing information concerning drive frequencies for a first drive voltage of said ultrasonic motor and information concerning drive frequencies for a second drive voltage lower than the first drive voltage,

a detecting means for detecting a driving condition of said ultrasonic motor,

a control means which selects said second drive voltage and a drive frequency where approximately maximum starting torque is obtainable with said second drive voltage based on the information stored in said storage means, and selects, if the driving condition detected by said detecting means reaches an appointed condition, said first drive voltage and a frequency where approximately maximum starting torque is obtainable with said first drive voltage, and selects, if the driving condition detected by said detecting means reaches an appointed condition, a drive frequency where a target number of revolutions is obtainable with said first drive voltage based on the information stored in said storage means, and

a driving force supplying means for supplying a drive signal based on the drive voltage and drive frequency selected by said control means to said piezoelectric body of said ultrasonic motor.

[0008] A fourth solution means is a device control unit for an ultrasonic motor as set forth in the solution means 1 through 3, wherein said storage means stores the relationship between the drive frequency, starting torque, and number of revolutions of said ultrasonic motor. A fifth solution means is a device control unit for an ultrasonic motor as set forth in the solution means 1 through 4, wherein said detecting means detects the number of revolutions of said ultrasonic motor. A sixth solution means is a device control unit for an ultrasonic motor as set forth in the solution means 1 through 4, wherein said detecting means detects a signal from a monitor electrode of said ultrasonic motor. A seventh solution means is a device control unit for an ultrasonic motor as set forth in the solution means 1 through 4, wherein said detecting means detects the phase difference between an input signal of said ultrasonic motor and a signal from a monitor electrode of said ultrasonic motor.

[0009]

[Action] In the solution means according to the present

invention, the ultrasonic motor is driven, first, with a drive frequency where maximum starting torque is obtainable and, then, with a drive frequency where a target number of revolutions is obtainable. Accordingly, rise time at start-up is reduced.

[0010]

[Preferred Embodiment] Hereinafter, referring to the drawings, etc., an embodiment of the present invention will be explained in detail. Fig. 1 is a perspective view showing a construction of an embodiment of an ultrasonic motor which is preferable when applied to the present invention. In Fig. 1, the ultrasonic motor 1 is composed of a stator 2 and a mobile body 3 which are press-fitted. Furthermore, the stator 2 is composed of a piezoelectric body 2a and an elastic body 2b. Herein, the rotator 2 and the mobile body 3 are formed in an approximately annular shape (a ring shape), however, in Fig. 1, the rotator 2 and the mobile body 3 are partially cut and are illustrated so that these sections can be observed. The piezoelectric body 2a is excited when a drive signal is supplied and due to this excitation, progressive oscillatory waves are generated in the elastic body 2b. Due to these oscillatory waves, the mobile body 3 comes into contact with the stator 2 and is driven.

[0011] Fig. 2 is a block diagram showing a construction of an embodiment of the drive control unit for an ultrasonic motor

according to the present invention. This drive control unit 10 is composed of a drive circuit 11 which is electrically connected to the ultrasonic motor 1 of Fig. 1, a detecting means 12, a system control means 13, a storage means 14, and a selecting means 15. The drive circuit 11 is a circuit for supplying a drive signal to an input electrode of the piezoelectric body 2a of the ultrasonic motor 1. The detecting means 12 detects the number of revolutions of the ultrasonic motor 1. The system control means 13 controls a driving system of the ultrasonic motor 1. The storage means 14 holds, in storage, information concerning drive frequencies of the ultrasonic motor 1 such as, for example, the relationship between the drive frequency, starting torque, and number of revolutions or the relationship between these and the drive voltage. The selecting means 15 selects, based on a motion instructing signal issued from the system control means 13, a drive controlling value from the storage means 14.

[0012] Now, based on Fig. 3 and Fig. 4, a first embodiment of motions of the drive control unit for an ultrasonic motor according to the present invention will be described. Fig. 3 is a diagram showing a first embodiment of the characteristic curves of the ultrasonic motor 1. Also, Fig. 4 is a flowchart showing a first embodiment of motions of the drive control unit

10. Fig. 3 shows characteristics when the drive voltage of the ultrasonic motor 1 is fixed. Herein, since starting torque Ttarget with a target number of revolutions (a number of revolutions at which driving is desired) Ntarget and a corresponding drive frequency ftarget does not always coincide with the maximum starting torque Tmax, if drive is carried out with the drive frequency ftarget corresponding to the target number of revolutions Ntarget, drive is carried out with a frequency where the starting torque is not maximum. Therefore, in the present embodiment, drive is controlled as follows.

[0013] In Fig. 4, first, in step 101, the system control means 13 first sets the drive frequency to fTmax. Namely, the selecting means 15 receives an instruction from the system control means 13, selects a drive frequency fTmax for which maximum starting torque Tmax of the ultrasonic motor 1 is obtainable from the inside of the storage means 14, and transmits the drive frequency to the drive circuit 11. The drive circuit 11 supplies a drive signal based on this value to the piezoelectric body 2a.

[0014] Then, the process proceeds to step 102, the system control means 13 compares the greatness of a target number of revolutions Ntarget with a number of revolutions NTmax corresponding to the drive frequency fTmax. If Ntarget ≥ NTmax

(in the case of Fig. 3), the process proceeds to step 103. In step 103, the drive frequency is maintained with fTmax until the number of revolutions reaches NTmax. The detecting means 12 detects as to whether the number of rotations of the ultrasonic motor 1 has reached NTmax or not. When it is detected by the detecting means 12 that the number of revolutions has reached NTmax, the process proceeds to step 104, and the system control means 13 changes the drive frequency settings from fTmax to ftarget. Namely, the selecting means 15 receives an instruction from the system control means 13, selects a drive frequency ftarget corresponding to the target number of revolutions Ntarget from the inside of the storage means 14, and transmits the drive frequency to the drive circuit 11. The drive circuit 11 supplies a drive signal based on this value to the piezoelectric body 2a. Then, the process proceeds to the following step 105, and when the number of revolutions of the ultrasonic motor 1 reaches Ntarget, the process is finished.

[0015] On the other hand, if the comparison does not indicate Ntarget ≥ NTmax in step 102, the process proceeds to step 106 and the drive frequency is maintained with fTmax until the number of revolutions reaches Ntarget. When the number of revolutions reaches Ntarget, the process then proceeds to step

104 and processes similar to the foregoing are carried out.

[0016] Fig. 5 is a diagram where a rising condition at start-up of the ultrasonic motor 1 when processes as in the above were performed is compared with the prior art. By conventional control, that is, when drive is carried out, from the beginning, with a drive frequency ftarget corresponding to a target number of revolutions Ntarget, the time by which the target number of revolutions Ntarget is attained has been t2, whereas, by control according to the present invention, the target number of revolutions Ntarget can be attained by a time t1. Thus, rise time at start-up can be shortened. Accordingly, the current consumption product is reduced and driving efficiency and driving performance are improved.

[0017] In addition, in the aforementioned first embodiment, with respect to a fixed drive voltage, the drive frequency fTmax for which the maximum starting torque Tmax is obtainable and the drive frequency ftarget for which the target number of revolutions Ntarget is obtainable have been selected, however, it may be also possible to, by storing information concerning drive frequencies with respect to a plurality of drive voltages in the detecting means 14, first, select an optimum drive voltage and then to select, with respect to the drive voltage, a drive frequency fTmax for which the maximum starting torque

is obtainable and a drive frequency for which the target number of revolutions is obtainable (which corresponds to Claim 2).

[0018] Fig. 6 is a diagram showing a second embodiment of characteristic curves of the ultrasonic motor 1. Fig. 7 is a flowchart showing a second embodiment of motions of the drive control unit 10. Fig. 6 shows characteristics when drive voltage of the ultrasonic motor 1 is variable. Similar to the first embodiment, if drive is carried out with a drive frequency ftarget corresponding to a target number of revolutions Ntarget, drive is carried out with a frequency where the starting torque is not maximum. Therefore, in the present embodiment, drive is controlled based on the flow chart shown in Fig. 7.

[0019] In Fig. 7, first, in step 201, the system control means 13 first sets the drive voltage to V1 and, furthermore, sets the drive frequency to a drive frequency f1 for which maximum starting torque Tmax1 is obtainable at this time. Namely, the selecting means 15 receives an instruction from the system control means 13, selects a drive voltage V1 and a drive frequency f1 at which maximum starting torque Tmax1 at this time is obtainable from the inside of the storage means 14 for transmission to the drive circuit 11. The drive circuit 11 supplies a drive signal based on this value to the piezoelectric body 2a.

[0020] Until the number of revolutions at this time reaches N1, the drive voltage is maintained with V1 and the drive frequency, with f1. In step 202, when it is detected by the detecting means 12 that the number of revolutions has reached N1, the process proceeds to step 203. In step 203, the system control means 13 sets the drive voltage to V2 and, furthermore, sets the drive frequency to a drive frequency f2 for which maximum starting torque Tmax2 at this time is obtainable. Until the number of revolutions at this time reaches N2, the drive voltage is maintained with V2, and the drive frequency, with f2, and in step 204, when it is detected that the number of revolutions has reached N2, the process exceeds to the following step 205.

[0021] In step 205, the system control means 13 sets the drive voltage to V3 and, furthermore, sets the drive frequency to a drive frequency f3 for which maximum starting torque Tmax3 at this time is obtainable. Until the number of revolutions at this time reaches N3, the drive voltage is maintained with V3, and the drive frequency, with f3, and in step 206, when it is detected that the number of revolutions has reached N3, the process exceeds to the following step 207.

[0022] In step 207, while leaving the drive voltage V3 without change, the system control means 13 sets the drive frequency

to a drive frequency ftarget corresponding to a target number of revolutions Ntarget. Then, the process proceeds to step 208, and when the number of revolutions reaches the target number of revolutions Ntarget, the process is finished.

[0023] Thus, by first carrying out drive with the drive voltages V1 and V2, which are smaller than the target drive voltage V3, thereafter by carrying out drive at the target drive voltage V3, the time by which the target number of revolutions reaches N3 is shortened compared to the case where drive is carried out at the target drive voltage V3 from the beginning.

[0024] In the foregoing, an embodiment of the present invention has been described, however, the present invention is not limited to the aforementioned embodiments and can be variously modified without departing from the spirit thereof. For example, in the second embodiment, drive voltage modifications are set at the three steps (V1, V2, and V3), however, the number of steps is not limited hereto and may be set at any number of steps. In the embodiments, the detecting means 12 detected the number of revolutions of the ultrasonic motor 1, however, it is sufficient that the detecting means 12 can detect driving conditions of the ultrasonic motor 1, and it may be constructed so as to detect, for example, a signal from a monitor electrode the phase difference between an input signal of the ultrasonic

motor 1 and a signal from the monitor electrode.

[0025] In addition, since the ultrasonic motor 1 changes in its characteristics depending on temperature, by performing control while taking the temperature into consideration, the rise time at start-up can still be shortened. For example, by providing a temperature detector to detect temperature, a drive frequency or a drive voltage and a drive frequency may be set in accordance with the temperature. In such a case, it is preferable that in the storage means 14, the relationship between the drive frequency, starting torque, and number of revolutions according to each temperature or the relationship between these and the drive voltage has been stored.

[0026]

[Effects of the Invention] According to the ultrasonic motor of the present invention, since the rise time when the ultrasonic motor starts up is shortened, an improvement in rising response at start-up is realized. Thus, the power consumption product is reduced and driving efficiency can be improved.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] A perspective view showing a construction of an embodiment of an ultrasonic motor which is preferable when applied to the present invention.

[Fig. 2] A block diagram showing a construction of an embodiment of the drive control unit for an ultrasonic motor according to the present invention.

[Fig. 3] A diagram showing the first embodiment of characteristic curves of the ultrasonic motor 1.

[Fig. 4] A flowchart showing the first embodiment of motions of the drive control unit.

[Fig. 5] A diagram where a rising condition at start-up of the ultrasonic motor when processes according to the present invention were performed is compared with the prior art.

[Fig. 6] A diagram showing the second embodiment of characteristic curves of the ultrasonic motor 1.

[Fig. 7] A flowchart showing the second embodiment of motions of the drive control unit.

[Description of Symbols]

1 Ultrasonic motor

2 Stator

2a Piezoelectric body

2b Oscillating body

3 Mobile body

10 Drive control unit

11 Drive circuit

12 Detecting means

13 System control means

14 Storage means

15 Selecting means

Fig.1

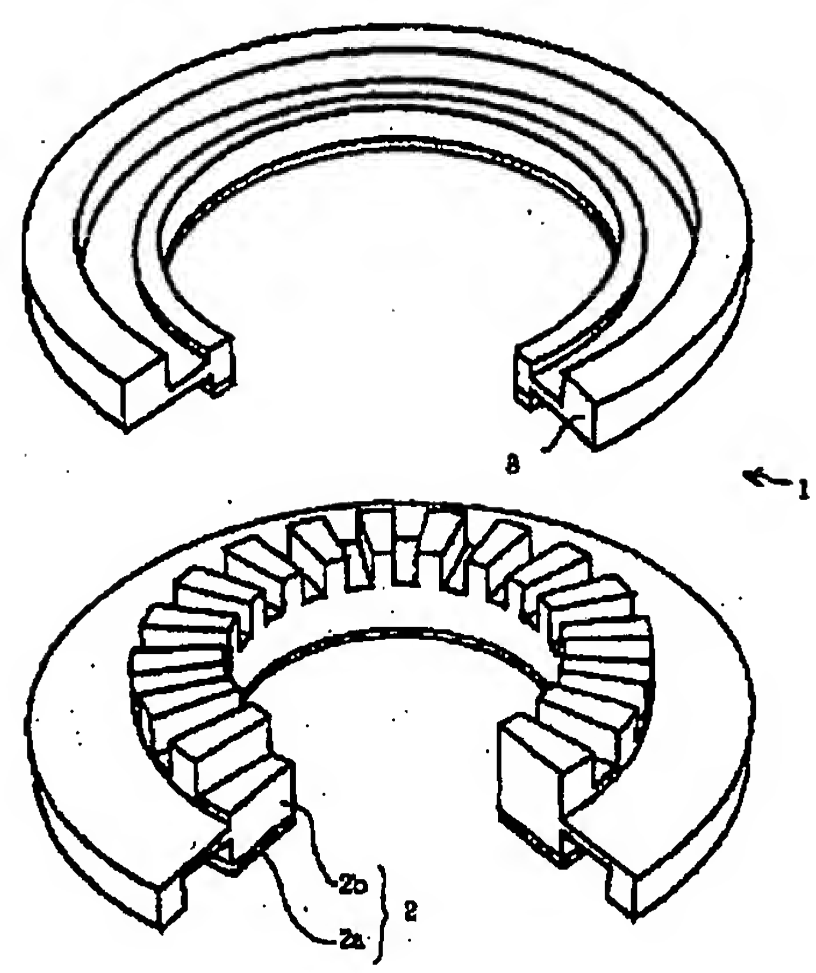


Fig.5

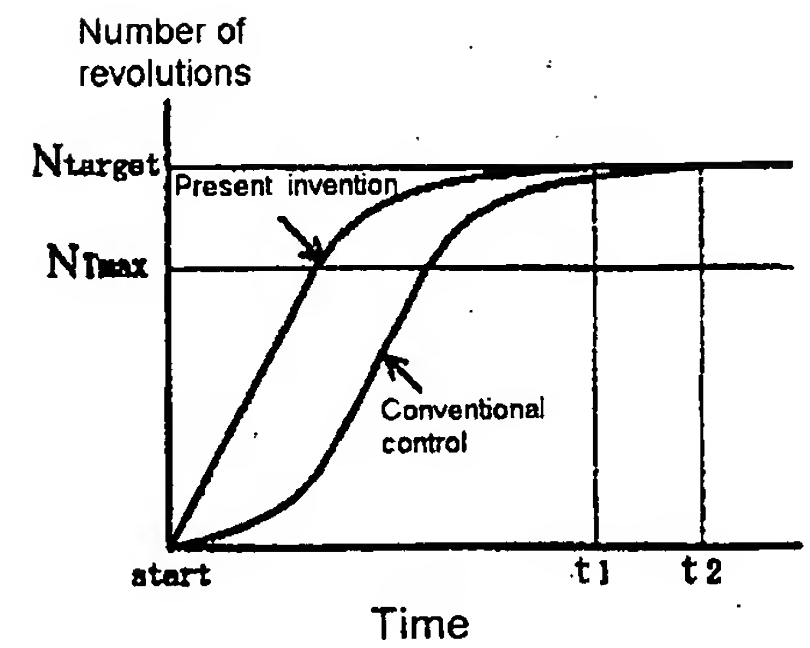


Fig.6

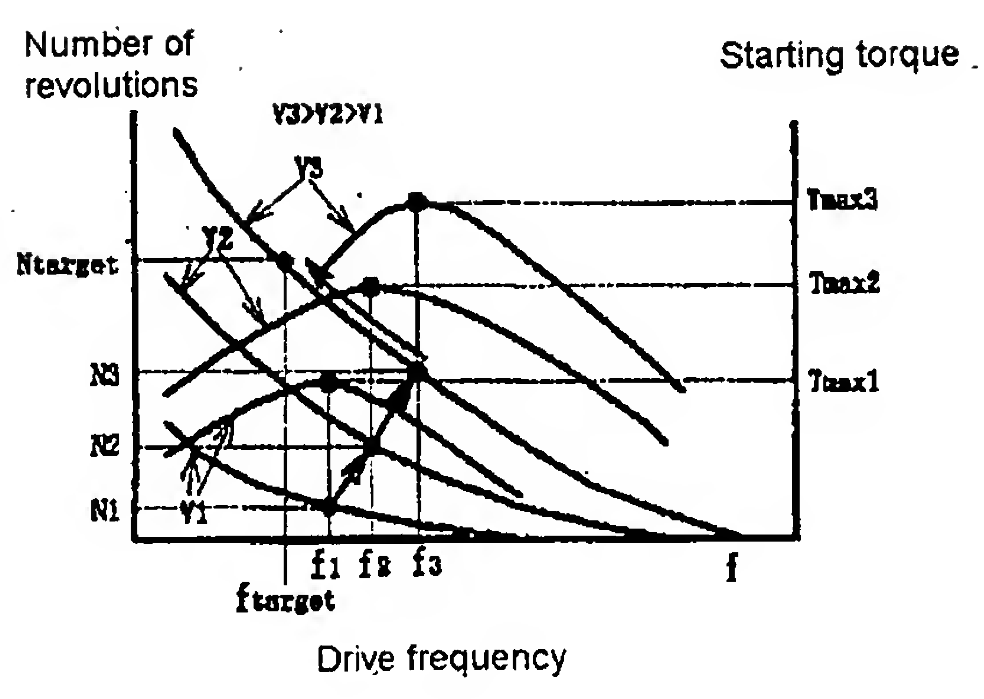


Fig.2

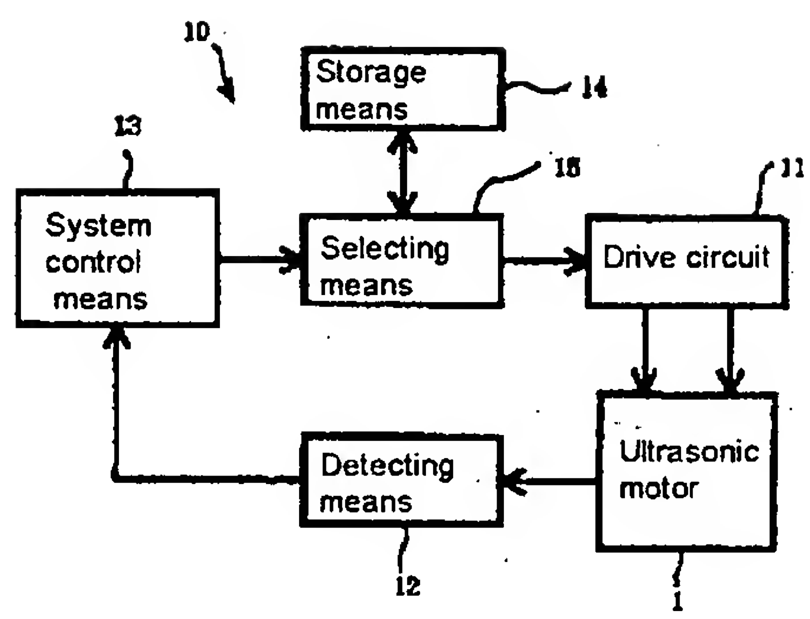
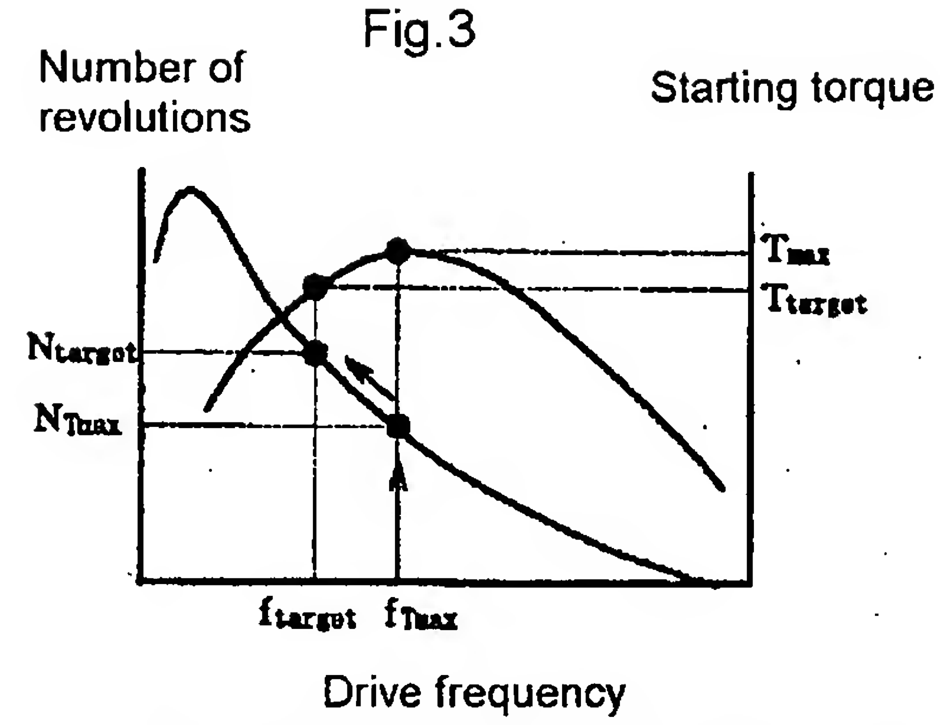
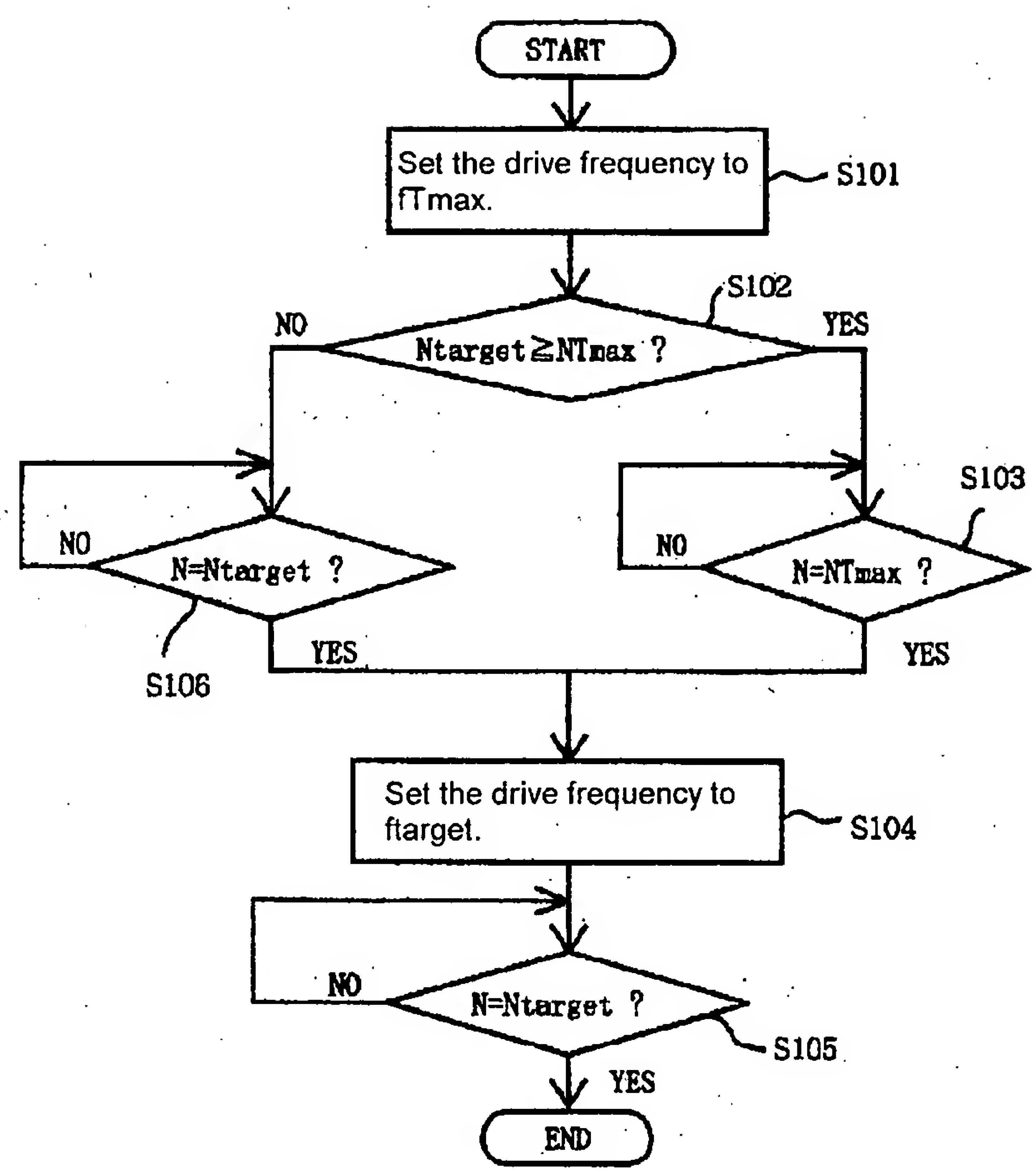


Fig.3



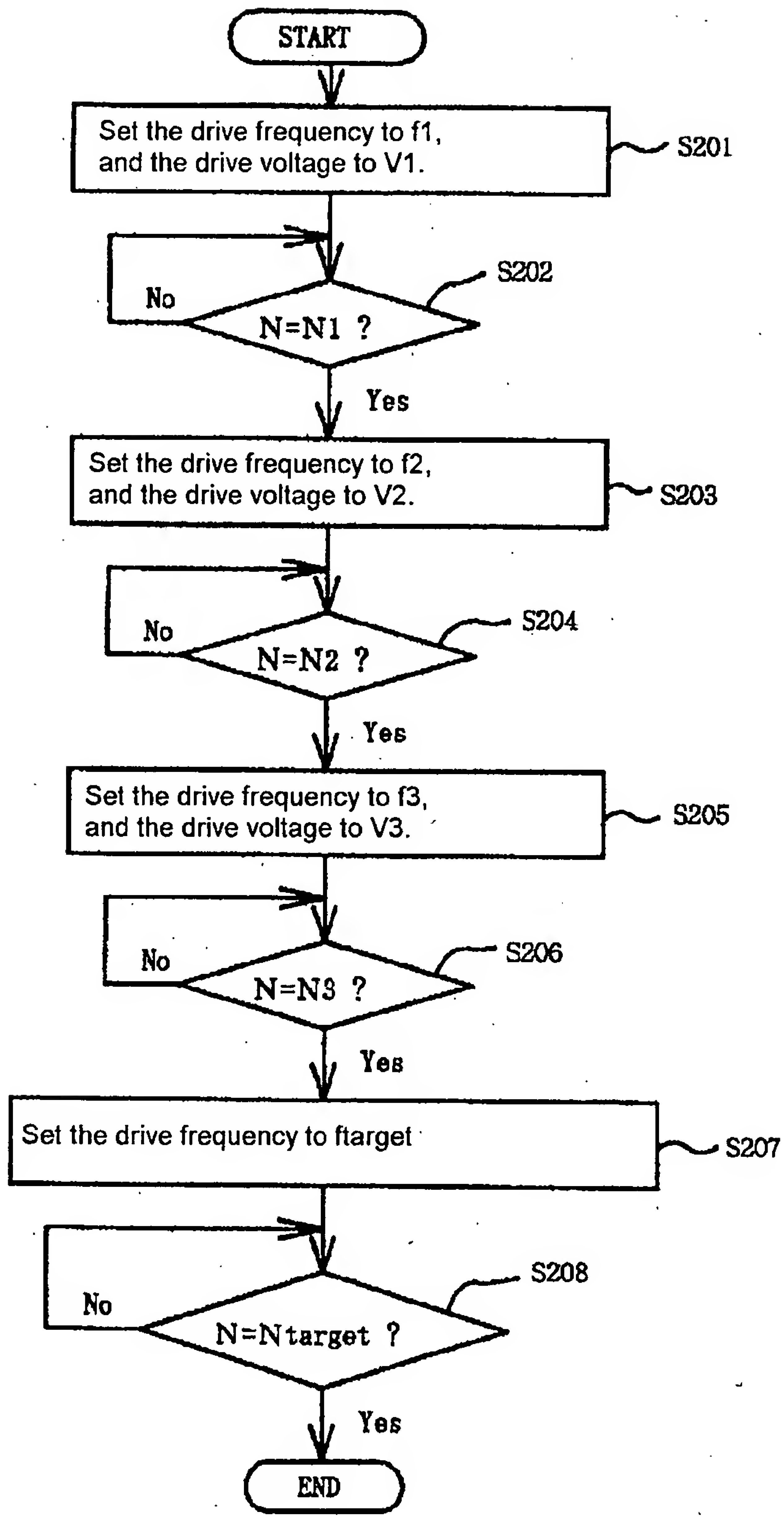
Characteristic curves of ultrasonic motor

Fig.4



START
Set the drive frequency to fTmax.
S101
S102
NO
YES
Ntarget≧NTmax ?
S103
NO
N=Ntarget ?
NO
N=NTmax ?
YES
YES
S106
Set the drive frequency to ftarget.
S104
NO
N=Ntarget ?
S105
YES
END

Fig.7



START
Set the drive frequency to f1,
and the drive voltage to V1.
S201
N=N1 ?
No
Yes
S202
Set the drive frequency to f2,
and the drive voltage to V2.
S203
N=N2 ?
No
Yes
S204
Set the drive frequency to f3,
and the drive voltage to V3.
S205
N=N3 ?
No
Yes
S206
Set the drive frequency to ftarget
S207
N=Ntarget ?
No
Yes
S208
END